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(54) Cloning and expression of bacillus thuringiensis toxin gene toxic to beetles of the order coleoptera.

(57) A Bacillus thuringiensis (disclosed in an earlier application) is now known as B. thuringiensis strain san diego. The toxin gene, toxic to beetles of the order Coleoptera , has been cloned and expressed.

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CLONING AND EXPRESSION OF BACILLUS THURINGIENSIS TOXIN GENE TOXIC TO BEETLES OF THE ORDER COLEOPTERA

This invention relates to the cloning and expression of Bacillus thuringiensis toxin gene toxic to beetles of the order Coleoptera.

The spore-forming microorganism Bacillus thuringiensis (Bt) produces the best known insect toxin, viz. a protein designated δ-endotoxin. It is synthetised by the Bt sporulating cell. The toxin, upon being ingested in its crystalline form by susceptible insect larvae, is transformed into biologically active moieties by gut juice proteases. The primary target is gut epithelial cells which are rapidly destroyed. Experience has shown that the activity of the Bt toxin is so high that only nanogram amounts are required to kill susceptible insect larvae.

The reported activity spectrum of Bt covers insect species within the order Lepidotera which constitutes a major insect problem in agriculture and forestry. The activity spectrum also includes the insect order Diptera which includes some species of mosquitos and blackflies. See Couch, (1980) "Mosquito Pathogenicity of Bacillus thuringiensis var. israelensis", Developments in Industrial Microbiology 22:61-67, and Beegle, (1978) "Use of Entomogenous Bacteria in Agroecosystems", Developments in Industrial Microbiology, 20:97-104.

Kreig et al, Z. ang. Ent. (1983) 96:500-508, describe a Bt isolate named Bacillus thuringiensis var. tenebrionis, which is reportedly active against two beetles of the order Coleoptera. These are Colorado potato beetle, Leptinotarsa decemlineata and Agelastica alni. This is the only known Bt isolate reported to have such activity; all previously identified Bt strains have has activity against caterpillars (order Lepidoptera) or larvae of certain flies (order Diptera). The isolate is not available to the public.

According to the present invention, a gene toxic to beetles of the order Coleoptera is cloned and expressed. The toxin produced by the cloned gene has activity against beetles of the order Coleoptera but not against Trichoplusia ni, Spodoptera exigua or Aedes aegypti. Included in the Coleoptera are various Diabrotica species (family Chrysomelidae) which are responsible for large agricultural losses in the USA at least, e.g. D. undecipunctata (western spotted cucumber beetle), D. longicornis (northern corn rootworm), D. virgitera (western corn rootworm) and D. undecimpunctata howardi (southern corn rootworm).

The Bacillus thuringiensis isolate used as the source of the toxin gene of the present invention, designated "M-7", is unusual in having a unique parasporal body (crystal) which under phase contrast microscopy is dark in appearance and has a flat; square configuration. This isolate is described and claimed in European Patent Application No. 86302126.7. A subculture of B. thuringiensis M-7, now known as B. thuringiensis strain san diego (B.t.sd.), has been deposited in the permanent collection of the Northern Regional Research Laboratory, U.S. Department of Agriculture, Peoria, Illinois, USA.

Another deposit relevant to the present invention has been made at the ARS Patent Collection, Culture Collection Research-Fermentation Laboratory, Northern Regional Research Center, Peoria, Illinois 61604, USA, i.e. of plasmid pCH-B3 in an E. coli host.

Deposit	Date	Accession No.
B.t.sd.	27 Feb. 1985	NRRL B-15939
E. coli (pCH-B3)	18 July 1985	NRRL B-15981

B. thuringiensis strain san diego, NRRL B-15939, can be cultured using conventional, standard media and fermentation techniques. Upon completion of the fermentation cycle, the bacteria can be harvested by first separating the Bt spores and crystals from the fermentation broth by means well known in the art. The DNA (chromosomal and plasmid) from the cells can be isolated by standard procedures and purified by procedures well known in the art. For example, such procedures are disclosed by Maniatis et al, Molecular Cloning (1982), Cold Spring Harbor Laboratory. The purified DNA then can be digested with a suitable restriction endonuclease.

A gene bank of B.t.sd DNA then can be constructed. In the subject invention, the purified B.t.sd DNA, obtained as described above, was digested with the restriction endonuclease BamHI and cloned into the BamHI site of the well-known and available plasmid pBR322.

Once the gene bank of B.t.sd DNA was constructed, it then became necessary to construct a DNA probe to screen the gene bank. The construction of this critical DNA probe was initiated by the isolation of M-7 toxin crystals fron a culture of B.t.sd.

The recovered M-7 toxin crystals were purified by standard procedures and then digested with trypsin to produce peptide fragments. The amino acid sequences of several of these tryptic fragments was determined by standard procedures. Subsequently, after selection of certain sequences, a probe was chemically synthesized by known means. The resulting probe was labelled and hybridized by procedures known in the art. The net result was the detection of positive clones, i.e., those that hybridized to the constructed probe.

A representative of the positive clones was subjected to a western blot using rabbit anti M-7 crystal antiserum developed by standard procedures. Confirmation of the success of the cloning and expression of M-7 toxin was obtained when a positive reaction was observed with the positive clone and the antibody against M-7 toxin crystal.

The recombinant plasmids isolated from representative positive clones were found to have a 5.8 kb DNA fragment inserted into the BamHI site. This 5.8 kb DNA fragment was excised from a representative positive clone (pCH-B3) with Bam HI, purified, and then subcloned into the BamHI site of the known and available plasmid pRO1614 (J. Bact. [1982] 150:60; U.S. Patent No. 4,374,200). Plasmid pRO1614 is available from the Northern Regional Reseach Laboratory, address above, where its deposit number is NRRL B-12127. The plasmid is derived from pBR322 and has unique Hin dIII, BamHI, and SalI and Pvu II restriction sites; a PstI insertion includes the carbenicillin resistance gene and a P. aeruginosa replication system. Pseudomonas fluorescens was transformed with this constructed shuttle vector and the expression of M-7 toxin was verified by its identification on a western blot.

Plasmid pCH-B3, or plasmid pRO1614 with the 5.8 kb fragment insert, can be recovered from their bacterial hosts by well-known procedures, e.g., using the cleared lysate-isopycnic density gradient procedures. If desired, the 5.8 kb fragment can be excised from pRO1614 by digestion with BamHI and cloned into a different vector for transformation into another host. These procedures are all well known to persons skilled in the art.

The toxin gene of the subject invention can be introduced into a wide variety of microbial hosts. Expression of the toxin gene (M-7) results, directly or indirectly, in the intracellular production and maintenance of the pesticide. With suitable hosts, e.g., Pseudomonas , the microbes can be applied to the situs of beetles of the order Coleoptera where they will proliferate and be ingested by the susceptible beetles. The result is a control of the unwanted beetles. Alternatively, the microbe hosting the toxin M-7 gene can be treated under conditions that prolong the activity of the toxin produced in the cell. The treated cell then can be applied to the environment of target pest(s). The resulting product retains the toxicity of the M-7 toxin.

Where the M-7 toxin gene is introduced via a suitable vector into a microbial host, and said host is applied to the environment in a living state, it is essential that certain host microbes be used. Microorganism hosts are selected which are known to occupy the "phytosphere" (phylloplane, phyllosphere, rhizosphere, and/or rhizoplane) of one or more crops of interest. These microorganisms are selected so as to be capable of successfully competing in the particular environment (crop and other insect habitats) with the wild-type microorganisms, provide for stable maintenance and expression of the gene expressing the polypeptide pesticide, and, desirably, provide for improved protection of the pesticide from environmental degradation and inactivation.

A large number of microorganisms are known to inhabit the phylloplane (the surface of plant leaves) and/or the rhizosphere (the soil surrounding plant roots) of a wide variety of important crops. These microorganisms include bacteria, algae, and fungi. Of particular interest are microorganisms, such as bacteria, e.g., genera Pseudomonas, Erwinia, Serratia , Xanthomonas, Streptomyces, Rhizobium, Rhodopseudomonas, Agrobacterium, Acetobacter, Lactobacillus, Arthrobacter, Azotobacter, Leuconostoc, and Alcaligenes; fungi, particularly yeast, e.g., genera, Saccharomyces, Cryptococcus, Kluyveromyces, Sporobolomyces, Rhodotorula, and Aureobasidium. Of particular interest are such phytosphere bacterial species as Pseudomonas syringae, Pseudomonas fluorescens, Serratia marcescens, Acetobacter xylinum, Agrobacterium tumefaciens, Rhodopseudomonas spheroides, Xanthomonas campestris, Rhizobium melioti, Alcaligenes entrophus, and Azotobacter vinlandii; and phytosphere yeast species such as Rhodotorula rubra, R. glutinis , R. marina, R. aurantiaca, Cryptococcus albidus, C. diffluens, C. laurentii, Saccharomyces rosei, S. pretoriensis, S. cerevisiae, Sporobolomyces roseus, S. odorus , Kluyveromyces veronae, and Aureobasidium pollulans. Of particular interest are the pigmented microorganisms.

A wide variety of ways are available for introducing the M-7 gene expressing the toxin into the microorganism host under conditions which allow for stable maintenance and expression of the

gene. One can provide for DNA constructs which include the transcriptional and translational regulatory signals for expression of the toxin gene, the toxin gene under their regulatory control and a DNA sequence homologous with a sequence in the host organism, whereby integration will occur, and/or a replication system which is funtional in the host, whereby integration or stable maintenance will occur.

The transcriptional initiation signals will include a promoter and a transcriptional initiation start site. In some instances, it may be desirable to provide for regulative expression of the toxin, where expression of the toxin will occur only after release into the environment. This can be achieved with operators or a region binding to an activator or enhancers, which are capable of induction upon a change in the physical or chemical environment of the microorganisms. For example, a temperature sensitive regulatory region may be employed, where the organisms may be grown up in the laboratory without expression of a toxin, but upon release into the environment, expression would begin. Other techniques may employ a specific nutrient medium in the laboratory, which inhibits the expression of the toxin, where the nutrient medium in the environment would allow for expression of the toxin. For translational initiation, a ribosomal binding site and an initiation codon will be present.

Various manipulations may be employed for enhancing the expression of the messenger, particularly by using an active promoter, as well as by employing sequences, which enhance the stability of the messenger RNA. The initiation and translational termination region will involve stop codon(s), a terminator region, and optionally, a polyadenylation signal.

In the direction of transcription, namely in the 5' to 3' direction of the coding or sense sequence, the construct will involve the transcriptional regulatory region, if any, and the promoter, where the regulatory region may be either 5' or 3' of the promoter, the ribosomal binding site, the initiation codon, the structural gene having an open reading frame in phase with the initiation codon, the stop condon(s), the polyadenylation signal sequence, if any, and the terminator region. This sequence as a double strand may be used by itself for transformation of a microorganism host, but will usually be included with a DNA sequence involving a marker, where the second DNA sequence may be joined to the toxin expression construct or may be combined as a separate DNA fragment with the toxin expression construct during introduction of the DNA into the host.

By a marker is intended a structural gene which provides for selection of those hosts which have been modified or transformed. The marker will normally provide for selective advantage, for example, providing for biocide resistance, e.g., resistance to antibiotics of heavy metals; complementation, so as to provide prototrophy to an auxotrophic host, or the like. Preferably, complementation is employed, so that the modified host may not only be selected, but may also be competitive in the field. One or more markers may be employed in the development of the constructs, as well as for modifying the host. The organisms may be further modified by providing for a competitive advantage against other wild-type microorganisms in the field. For example, genes expressing metal chelating agents, e.g., siderophores, may be introduced into the host along with the structural gene expressing the toxin. In this manner, the enhanced expression of a siderophore may provide for a competitive advantage for the toxin producing host, so that it may effectively compete with the wild-type microorganisms and stably occupy a niche in the environment of the vegetation to be protected.

Where no functional replication system is present, the construct will also include a sequence of at least 50 bp, preferably at least about 100 bp, and usually not more than about 1000 bp of a sequence homologous with a sequence in the host. In this way, the probability of legitimate recombination is enhanced, so that the gene will be integrated into the host and stably maintained by the host. Desirably, the toxin gene will be in close proximity to the gene providing for complementation as well as the gene providing for the competitive advantage. Therefore, in the event that the toxin gene is lost, the resulting organism will be likely to also lose the complementing gene and/or the gene providing for the competitive advantage, so that it will be unable to compete in the environment with the gene retaining the intact construct.

A large number of transcriptional regulatory regions are available from a wide variety of microorganism hosts, such as bacteria, bacteriophage, cyanobacteria, algae, fungi, and the like. Various transcriptional regulatory regions include the regions associated with the trp gene, lac gene, gal gene, the lambda left and right promoters, the Tac promoter, the naturally-occurring promoters associated with the toxin gene, where functional in the host. See for example, U.S. Patent Nos. 4,332,898; 4,342,832 and 4,356,270. The termination region may be the termination region normally associated with the transcriptional initiation region or a different transcriptional initiation region, so long as the two regions are compatible and functional in the host.

Where stable episomal maintenance or integration is desired, a plasmid will be employed which has a replication system which is functional in the host. The replication system may be derived from the chromosome, an episomal element normally present in the host or a different host, or a replication system from a virus which is stable in the host. A large number of plasmids are available, such as pBR322, pACYC184, RSF1010, pRO1614, and the like. See for example, Olson et al., (1982) J. Bacteriol. 150:6069,and Bagdasarian et al., (1981) Gene 16:237, and U.S. Patent Nos. 4,356,270; 4,362,817; and 4,371,625.

The M-7 gene can be introduced between the transcriptional and translational initiation region and the transcriptional and translational termination region, so as to be under the regulatory control of the initiation region. This construct will be included in a plasmid, which will include at least one replication system, but may include more than one, where one replication system is employed for cloning during the development of the plasmid and the second replication system is necessary for functioning in the ultimate host. In addition, one or more markers may be present, which have been described previously. Where integration is desired, the plasmid will desirably include a sequence homologous with the host genome.

The transformants can be isolated in accordance with conventional ways, usually employing a selection technique, which allows for selection of the desired organism as against unmodified organisms or transferring organisms, when present. The transformants then can be tested for pesticidal activity.

Preferred hosts, particularly those in the phytosphere, will have certain characteristics which enhance the environmental stability of the toxins in the host. Protective qualities include a low level of proteolytic degradation, thick cell walls, pigmentation, and the like. Other characteristics of interest for the host include leaf affinity, lack of mammalian toxicity, attractiveness to pests for ingestion, ease of handling and storage, rate of proliferation in the field, competitiveness, and the like.

In the field applications, the transformant strain will be applied to its natural habitat, such as the rhizosphere or phylloplane of the plant to be protected from the pest. The transformant strain will grow in its natural habitat, while producing the M-toxin which will be absorbed and/or ingested by the larvae or adult pest, or have a toxic effect on the ova. The persistence of the microorganisms will provide for long-term protection of the vegetation, although repetitive administrations may be required from time to time. The organism may be applied by spraying, soaking, injection into the soil, seed coating, seedling coating or spraying, or the like. Where administered in the field, generally concentrations of the organism will be from 10^5 to 10^{10} cells/ml, and the volume applied per hectare will be generally from 0.025 to 1 kg or more. Where administered to a plant part, the concentration of the organism will usually be from 10^3 to 10^6 cells/cm^2.

Suitable host cells, where the pesticide-containing cells will be treated to prolong the activity of the toxin in the cell when the then dead cell is applied to the environment of target pest(s), may include either prokaryotes or eukaryotes, normally being limited to those cells which do not produce substances toxic to higher organisms, such as mammals. However, organisms which produce substances toxic to higher organisms could be used, where the toxin is unstable or the level of application sufficiently low as to avoid any possibility of toxicity to a mammalian host. As hosts, of particular interest will be the prokaryotes and lower eukaryotes, such as fungi. Illustrative prokaryotes, both Gram-negative and -positive, include Enterobacteriaceae, such as Escherichia, Erwinia, Shigella, Salmonella, and Proteus; Bacillaceae; Rhizobiaceae, such as Rhizobium; Spirillaceae, such as photobacterium, Zymomonas, Serratia, Aeromonas, Vibrio, Desulfovibrio, Spirillum; Lactobacillaceae; Pseudomonadaceae, such as Pseudomonas and Acetobacter; Azotobacteraceae and Nitrobacteraceae. Among eukaryotes are fungi, such as Phycomycetes and Ascomycetes, which includes yeast, such as Saccharomyces and Schizosaccharomyces ; and Basidiomycetes yeast, such as Rhodotorula, Aureobasidium, Sporobolomyces, and the like.

Characteristics of particular interest in selecting a host cell for purposes of production include ease of introducing the M-7 gene into the host, availability of expression systems, efficiency of expression, stability of the pesticide in the host, and the presence of auxiliary genetic capabilities. Characteristics of interest for use as a pesticide microcapsule include protective qualities for the pesticide, such as thick cell walls, pigmentation, and intracellular packaging or formation of inclusion bodies; leaf affinity; lack of mammalian toxicity; attractiveness to pests for ingestion; ease of killing and fixing without damage to the toxin; and the like. Other considerations include ease of formulation and handling, economics, storage stability, and the like.

Host organisms of particular interest include yeast, such as Rhodotorula sp., Aureobasidium sp., Saccharomyces sp., and Sporobolomyces sp., phylloplane organisms such as Pseudomonas sp., Erwinia sp. and Flavobacterium sp.; or such other organisms as Escherichia, Lactobacillus sp., Bacillus sp., and the like. Specific organisms include

Pseudomonas aeruginosa, Pseudomonas fluorescens, Saccharomyces cerevisiae, Bacillus thuringiensis, Escherichia coli, Bacillus subtilis, and the like.

The cell will usually be intact and be substantially in the proliferative form when killed, rather than in a spore form, although in some instances spores may be employed.

The cells may be inhibited from proliferation in a variety of ways, so long as the technique does not deleteriously affect the properties of the pesticide, nor diminish the cellular capability in protecting the pesticide. The techniques may involve physical treatment, chemical treatment, changing the physical character of the cell or leaving the physical character of the cell substantially intact, or the like.

Various techniques for inactivating the host cells include heat, usually 50°C to 70°C; freezing; UV irradiation; lyophilization; toxins, e.g., antibiotics; phenols; anilides, e.g., carbanilide and salicylanilide; hydroxyurea; quaternaries; alcohols; antibacterial dyes; EDTA and amidines; non-specific organic and inorganic chemicals, such as halogenating agents, e.g., chlorinating, brominating or iodinating agents; aldehydes, e.g., glutaraldehyde or formaldehyde; toxic gases, such as ozone and ethylene oxide; peroxide; psoralens; desiccating agents or the like, which may be used individually or in combination. The choice of agent will depend upon the particular pesticide, the nature of the host cell, the nature of the modification of the cellular structure, such as fixing and preserving the cell wall with crosslinking agents, or the like.

The cells generally will have enhanced structural stability which will enhance resistance to environmental degradation in the field. Where the pesticide is in a proform, the method of inactivation should be selected so as not to inhibit processing of the proform to the mature form of the pesticide by the target pest pathogen. For example, formaldehyde will crosslink proteins and could inhibit processing of the proform of a polypeptide pesticide. The method of inactivation or killing retains at least a substantial portion of the bioavailability or bioactivity of the toxin.

The cellular host containing the M-7 pesticidal gene may be grown in any convenient nutrient medium, where the DNA construct provides a selective advantage, providing for a selective medium so that substantially all or all of the cells retain the M-7 gene. These cells may then be harvested in accordance with conventional ways. Alternatively, the cells can be fixed prior to harvesting.

The method of treating the host organism containing the toxin can fulfill a number of functions. First, it may enhance structural integrity. Second, it may provide for enhanced proteolytic stability of the toxin, by modifying the toxin so as to reduce its suceptibility to proteolytic degradation and/or by reducing the proteolytic activity of proteases naturally present in the cell. The cells are preferably modified at an intact stage and when there has been a substantial build-up of the toxin protein. These modifications can be achieved in a variety of ways, such as by using chemical reagents having a broad spectrum of chemical reactivity. The intact cells can be combined with a liquid reagent medium containing the chemical reagents, with or without agitation, at temperatures in the range of about -10 to 60°C. The reaction time may be determined empirically and will vary widely with the reagents and reaction conditions. Cell concentrations will vary from about 10^2 to 10^{10} per ml.

Of particular interest as chemical reagents are halogenating agents, particularly halogens of atomic no. 17-80. More particularly, iodine can be used under mild conditions and for sufficient time to achieve the desired results. Other suitable techniques include treatment with aldehydes, such as formaldehyde and glutaraldehyde; anti-infectives, such as zephiran chloride and cetylpyridinium chloride; alcohols, such as isopropyl and ethanol; various histologic fixatives, such as Bouin's fixative and Helly's fixative (see Humason, Gretchen L., Animal Tissue Techniques, W.H. Freeman and Company, 1967); or a combination of physical (heat) and chemical agents that prolong the activity of the toxin produced in the cell when the cell is applied to the environment of the target pest(s).

For halogenation with iodine, temperatures will generally range from about 0 to 50°C, but the reaction can be conveniently carried out at room temperature. Conveniently, the iodination may be performed using triiodide or iodine at 0.5 to 5% in an acidic aqueous medium, particularly an aqueous carboxylic acid solution that may vary from about 0.5-5M. Conveniently, acetic acid may be used, although other carboxylic acids, generally of from about 1 to 4 carbon atoms, may also be employed. The time for the reaction will generally range from less than a minute to about 24 hr, usually from about 1 to 6 hr. Any residual iodine may be removed by reaction with a reducing agent, such as dithionite, sodium thiosulfate, or other reducing agent compatible with ultimate usage in the field. In addition, the modified cells may be subjected to further treatment, such as washing to remove all of the reaction medium, isolation in dry form, and formulation with typical stickers, spreaders, and adjuvants generally utilized in agricultural applications, as is well known to those skilled in the art.

Of particular interest are reagents capable of crosslinking the cell wall. A number of reagents are known in the art for this purpose. The treatment should result in enhanced stability of the pesticide. That is, there should be enhanced persistence or residual activity of the pesticide under field conditions. Thus, under conditions where the pesticidal activity of untreated cells diminishes, the activity of treated cells remains for periods of from 1 to 3 times longer.

The cells may be formulated in a variety of ways. They may be employed as wettable powders, granules or dusts, by mixing with various inert materials, such as inorganic minerals - (phyllosilicates, carbonates, sulfates, phosphates, and the like) or botanical materials (powdered corncobs, rice hulls, walnut shells, and the like). The formulations may include spreader-sticker adjuvants, stabilizing agents, other pesticidal additives, or surfactants. Liquid formulations may be aqueous-based or non-aqueous and employed as foams, gels, suspensions, emulsifiable concentrates, or the like. The ingredients may include rheological agents, surfactants, emulsifiers, dispersants, or polymers.

The pesticidal concentration will vary widely depending upon the nature of the particular formulation, particularly whether it is a concentrate or to be used directly. The pesticide will be present in at least 1% by weight and may be 100% by weight. The dry formulations will have from about 1-95% by weight of the pesticide while the liquid formulations will generally be from about 1-60% by weight of the solids in the liquid phase. The formulations will generally have from about 10^2 to about 10^4 cells/mg. These formulations will be administered at about 50 mg (liquid or dry) to 1 kg or more per hectare.

The formulations can be applied to the environment of the pest(s), e.g., plants, soil or water, by spraying, dusting, sprinkling or the like.

Following are examples which illustrate procedures, including the best mode, for practicing the invention. These examples should not be construed as limiting. All percentages are by weight and all solvent mixture proportions are by volume unless otherwise noted.

Example 1—Culturing B. thuringiensis strain sandiego NRRL B-15939.

A subculture or starter culture of B. thuringiensis strain san diego NRRL B-15939 can be used to inoculate the following medium, known as LB broth:

Tryptone	10 gm
Yeast extract	5 gm
NaCl	5 gm
5N NaOH	0.6 ml
Water	1000 ml

As per standard microbiological techniques, the above medium would be sterilized prior to inoculation and the inoculations would be done using aseptic procedures. The M-7 cells are grown for 3-4 days at 30°C.

A detailed procedure is as given in EPA 86302126.7:

A series of 150 ml Erlenmeyer flasks containing sterile PWYE medium (peptone 5.0%; yeast extract 0.1%; NaCl 0.5% in 1 liter of water; adjust pH to 7.5) are inoculated from a petri plate culture of B. thuringiensis strain san diego, NRRL B-15939. The flasks are incubated at 30°C on a rotary shaker (200 rpm) overnight. From this starter culture, 300 ml of LB broth in a 2-liter flask is inoculated using 7.5 ml of the starter. The LB-broth flasks are incubated under the same conditions as the starter, but are harvested after 4 days.

The above procedure can be readily scaled up to large fermentors by procedures well known in the art.

The Bt spores and crystals, obtained in the above fermentation, can be isolated by procedures well known in the art. A frequently-used procedure is to subject the harvested fermentation broth to separation techniques, e.g., centrifugation.

Example 2—Cloning and Expression of M-7 Toxin Gene

Total DNA (chromosomal and plasmid) was isolated from the M-7 cells of Example 1 and purified by standard procedures. The resulting purified DNA was digested with the restriction endonuclease BamHI, using the supplier's instruction. The digested DNA was then cloned into the BamHI

site of the well-known plasmid pBR322 to give a gene bank of M-7 DNA. This cloning procedure was done following standard well-known procedures.

A DNA probe to screen the gene bank was obtained as follows: M-7 crystals were isolated from a culture grown in NYSM medium (10 gm tryptone, 5 gm NaCl, 5 gm yeast extract, 2 gm $MgSO_4 \cdot 7H_2O$, 1000 ml water, pH 7.5) overnight at 30°C. The purified crystals were dissolved in 8 M urea, 0.1 M glycine, pH 8.2 and digested with trypsin overnight at room temperature. The resulting peptide fragments were separated on a C_4 reverse phase high pore column with 180 min gradient of 91% solution A (0.1% trifluoroacetic acid in H_2O) to 40% solution A in 0.1% trifluoroacetic acid in acetonitrile. The aminoacid sequences of several tryptic fragments were obtained and a sequence of 6 aminoacids were selected for synthesis of a mixed probe, 17 bases in length, with a redundancy of 32.

The probe was end-labeled with polynucleotide kinase and [γ-^{32}P]ATP and hybridized to bacterial colonies containing recombinant plasmids as constructed for the M-7 gene bank. The colony filters were prepared according to Hanahan and Meselson (1980) Gene 10:63-67. Positive colonies were identified by autoradiography. The recombinant plasmids isolated from seven positive clones (pCH-B3 as representative) were found to have a 5.8 kb - (kilobase pairs) DNA fragment inserted into the BamHI site.

A western blot (Burnette, W.N. [1981] Anal. Biochem. 112:195) of pCH-B3 was performed on an SDS-PAGE of an overnight culture, using rabbit anti-M-7 crystal anti-serum. A protein of about 86 kilodalton was identified. The clone pCH-B3, therefore, contains an M-7 DNA fragment that encodes for a protein having serological identity with the protein from the M-7 crystals. The recombinant protein may be bigger than the toxin from solubilized M-7 crystals because of unavailability of transcriptional and/or translational stop signals in the given plasmid construction.

The nucleotide sequence encoding the B.t.sd toxin gene is shown in Table A. The deduced amino acid sequence is shown in Table B.

As is well known in the art, the amino acid sequence of a protein is determined by the nucleotide sequence of the DNA. Because of the redundancy of the genetic code, i.e., more than one coding nucleotide triplet (codon) can be used for most of the amino acids used to make proteins, different nucleotide sequences can code for a particular amino acid. Thus, the genetic code can be depicted as follows: Phenylalanine (Phe) TTK

Leucine (Leu) XTY

Isoleucine (Ile) ATM

Methionine (Met) ATG

Valine (Val) GTL

Serine (Ser) QRS

Proline (Pro) CCL

Threonine (Thr) ACL

Alanine (Ala) GCL

Tyrosine (Tyr) TAK

Termination signal TAJ

Histidine (His) CAK

Glutamine (Gln) CAJ

Asparagine (Asn) AAK

Lysine (Lys) AAJ

Aspartic acid (Asp) GAK

Glutamic acid (Glu) GAJ

Cysteine (Cys) TGK

Tryptophan (Trp) TGG

Arginine (Arg) WGZ

Glycine (Gly) GGL

Key: Each 3-letter deoxynucleotide triplet corresponds to a trinucleotide of mRNA, having a 5'-end on the left and a 3'-end on the right. All DNA sequences given herein are those of the strand whose sequence corresponds to the mRNA sequence, with thymine substituted for uracil. The letters stand for the purine or pyrimidine bases forming the deoxynucleotide sequence.

A = adenine

G -guanine

C = cytosine

T = thymine

X = T or C if Y is A or G

X = C if Y is C or T

Y = A, G, C or T if X is C

Y = A or G if X is T

W = C or A if Z is A or G

W = C if Z is C or T

Z = A, G, C or T if W is C

Z = A or G if W is A

QR = TC if S is A, G, C or T; alternatively QR = AG if S is T or C

J = A or G

K = T or C

L = A, T, C or G

M -A, C or T

The above shows that the novel amino acid sequence of the M7 toxin, and other useful proteins, can be prepared by equivalent nucleotide sequences encoding the same amino acid sequence of the proteins. Accordingly, the subject invention includes such equivalent nucleotide sequences. In addition it has been shown that proteins of identified structure and function may be constructed by changing the amino acid sequence if such changes do not alter the protein secondary structure (Kaiser, E.T. and Kezdy, F.J. [1984] Science 223:249-255). Thus, the subject invention includes mutants of the amino acid sequence depicted herein which do not alter the protein secondary structure, or if the structure is altered, the biological activity is retained to some degree.

Example 3--Production of M-7 Toxin Protein by Clone pCH-B3

A 20 liter culture of pCH-B3 (L-broth with 70 µg/ml Ampicillin) was grown in a fermenter and harvested at OD600=3.35. The cell pellet was washed with water and resuspended in 500 ml glycine buffer (0.1 M glycine, pH 8.0 with tris base) containing 2 g lysozyme, ImM PMSF - (phenylmethylsulfonyl fluoride), 1 mM TPCK (1-tosylamide-2-phenyl ethylchloromethyl ketone), and 500 µg DNase I and incubated at room temperature for 30 min. The pH was then raised to 10 with NaOH and the cells were further ruptured in a bead beater (Biospec Products, Bartlesville, OK) on ice with four 30 second bursts 5 min apart. The extract was then centrifuged at 10,000 x g for 30 min.

Example 4--Isolation and Purification of M-7 Toxin Protein Produced by Clone pCH-B3

The protein from pCH-B3 was purified using affinity chromatography (Cuatrecasa, P. and Anfinsen, C.B. [1971] Meth. Enzymology Vol. 22 [ed. W.B. Jacoby] Acad. Press, N.Y.) as follows: Sepharose was activated with cyanogen bromide as described by Cuatrecasa and Anfinsen. Rabbit anti-M-7 crystal serum was added to the activated Sepharose and incubated overnight at room temperature with constant agitation. The affinity resign was then washed with 1% ethanolamine, 3 M NaCl, pH 9.2, and then with TBS (0.02 M tris-HCl, 0.07 M NaCl, pH 7.5) containing 0.02% sodium azide. The column was equilibrated in 0.1 M glycine pH 10 - (with tris base) containing 1 mM EDTA (ethylenediaminetetraacetic acid), 1 mM PMSF, 1 mM TPCK, and 0.02% sodium azide. The E. coli extract, prepared above, was loaded onto the column and recirculated for 64 hr at 4°C. The extract was washed from the column with 1 M NaCl and 0.1 M glycine-tris pH 10, and the bound M-7 toxin was removed from the column with 3 M sodium perchlorate, 0.1 M glycine-tris pH 10. The M-7 toxin was then dialyzed against water and concentrated (Micro-Pro D: Con, Pierce Chem. Co., Rockford, IL).

The purified M-7 toxin can be administered to vegetation susceptible to infestation by beetles of the order Coleoptera, to protect the vegetation. The M-7 toxin is preferably made environmentally stable by use of suitable conventional coatings.

Example 5 Subcloning and Expression of M-7 Toxin Gene into Pseudomonas fluorescens

The 5.8 kb DNA fragment carrying the M-7 toxin gene was excised from plasmid pCH-B3 with Bam HI, purified and subcloned into the BamHI site of the plasmid pRO1614. Pseudomonas fluorescens was transformed with this plasmid. The expression of M-7 toxin by recombinant Pseudomonas cells was verified by its identification on a western blot.

Testing

B. thuringiensis strain san diego NRRL B-15939 spores and crystal, obtained as described above, were tested against various insects. The insect species are given (together with results) in Table C; they are all of the Coleoptera family except Culicidae (family Diptera) and Noctuidae - (family Lepidoptera).

The method used to test for D. undecimpunctata, and the results of two bioassays are given on page 7 of EPA 86302126.7.

In order to test the M-7 toxin for activity against Pyrrhalta luteola (elm leaf beetle), a suspension of solubilized protein from M-7 crystals was applied to elm leaves. The dried leaves were then placed in a container on moist sand. Five to ten larvae of P. luteola were added and the containers were incubated at room temperature. Mortality was recorded at 3 and 5 days. An LC_{50} of 120 ng toxin/cm² of leaf surface was calculated from these assays.

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Table A

Nucleotide Sequence Encoding the Bacillus thuringiensis strain san diego Toxin Gene

ATGA ATCCGAACAA
TCGAAGTGAA CATGATACAA TAAAAACTAC TGAAAATAAT GAGGTGCCAA
CTAACCATGT TCAATATCCT TTAGCGGAAA CTCCAAATCC AACACTAGAA
GATTTAAATT ATAAAGAGTT TTTAAGAATG ACTGCAGATA ATAATACGGA
AGCACTAGAT AGCTCTACAA CAAAAGATGT CATTCAAAAA GGCATTTCCG
TAGTAGGTGA TCTCCTAGGC GTAGTAGGTT TCCCGTTTGG TGGAGCGCTT
GTTTCGTTTT ATACAAACTT TTTAAATACT ATTTGGCCAA GTGAAGACCC
GTGGAAGGCT TTTATGGAAC AAGTAGAAGC ATTGATGGAT CAGAAAATAG
CTGATTATGC AAAAAATAAA GCTCTTGCAG AGTTACAGGG CCTTCAAAAT
AATGTCGAAG ATTATGTGAG TGCATTGAGT TCATGGCAAA AAAATCCTGT
GAGTTCACGA AATCCACATA GCCAGGGGCG GATAAGAGAG CTGTTTTCTC
AAGCAGAAAG TCATTTTCGT AATTCAATGC CTTCGTTTGC AATTTCTGGA
TACGAGGTTC TATTTCTAAC AACATATGCA CAAGCTGCCA ACACACATTT
ATTTTTACTA AAAGACGCTC AAATTTATGG AGAAGAATGG GGATACGAAA
AAGAAGATAT TGCTGAATTT TATAAAAGAC AACTAAAACT TACGCAAGAA
TATACTGACC ATTGTGTCAA ATGGTATAAT GTTGGATTAG ATAAATTAAG
AGGTTCATCT TATGAATCTT GGGTAAACTT TAACCGTTAT CGCAGAGAGA
TGACATTAAC AGTATTAGAT TTAATTGCAC TATTTCCATT GTATGATGTT
CGGCTATACC CAAAAGAAGT TAAAACCGAA TTAACAAGAG ACGTTTTAAC
AGATCCAATT GTCGGAGTCA ACAACCTTAG GGGCTATGGA ACAACCTTCT
CTAATATAGA AAATTATATT CGAAAACCAC ATCTATTTGA CTATCTGCAT
AGAATTCAAT TTCACACGCG GTTCCAACCA GGATATTATG GAAATGACTC
TTTCAATTAT TGGTCCGGTA ATTATGTTTC AACTAGACCA AGCATAGGAT
CAAATGATAT AATCACATCT CCATTCTATG GAAATAAATC CAGTGAACCT
GTACAAAATT TAGAATTTAA TGGAGAAAAA GTCTATAGAG CCGTAGCAAA
TACAAATCTT GCGGTCTGGC CGTCCGCTGT ATATTCAGGT GTTACAAAAG
TGGAATTTAG CCAATATAAT GATCAAACAG ATGAAGCAAG TACACAAACG
TACGACTCAA AAAGAAATGT TGGCGCGGTC AGCTGGGATT CTATCGATCA
ATTGCCTCCA GAAACAACAG ATGAACCTCT AGAAAAGGGA TATAGCCATC
AACTCAATTA TGTAATGTGC TTTTTAATGC AGGGTAGTAG AGGAACAATC
CCAGTGTTAA CTTGGACACA TAAAAGTGTA GACTTTTTTA ACATGATTGA
TTCGAAAAAA ATTACACAAC TTCCGTTAGT AAAGGCATAT AAGTTACAAT
CTGGTGCTTC CGTTGTCGCA GGTCCTAGGT TTACAGGAGG AGATATCATT
CAATGCACAG AAAATGGAAG TGCGGCAACT ATTTACGTTA CACCGGATGT
GTCGTACTCT CAAAAATATC GAGCTAGAAT TCATTATGCT TCTACATCTC
AGATAACATT TACACTCAGT TTAGACGGGG CACCATTTAA TCAATACTAT
TTCGATAAAA CGATAAATAA AGGAGACACA TTAACGTATA ATTCATTTAA
TTTAGCAAGT TTCAGCACAC CATTCGAATT ATCAGGGAAT AACTTACAAA
TAGGCGTCAC AGGATTAAGT GCTGGAGATA AAGTTTATAT AGACAAAATT
GAATTTATTC CAGTGAAT

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Table B

Deduced Amino Acid Sequence of Bacillus thuringiensis strain san diego Toxin

```
                5                  10                  15                  20
Met Asn Pro Asn Asn Arg Ser Glu His Asp Thr Ile Lys Thr Thr Glu Asn Asn Glu Val

               25                  30                  35                  40
Pro Thr Asn His Val Gln Tyr Pro Leu Ala Glu Thr Pro Asn Pro Thr Leu Glu Asp Leu

               45                  50                  55                  60
Asn Tyr Lys Glu Phe Leu Arg Met Thr Ala Asp Asn Asn Thr Glu Ala Leu Asp Ser Ser

               65                  70                  75                  80
Thr Thr Lys Asp Val Ile Gln Lys Gly Ile Ser Val Val Gly Asp Leu Leu Gly Val Val

               85                  90                  95                 100
Gly Phe Pro Phe Gly Gly Ala Leu Val Ser Phe Tyr Thr Asn Phe Leu Asn Thr Ile Trp

              105                 110                 115                 120
Pro Ser Glu Asp Pro Trp Lys Ala Phe Met Glu Gln Val Glu Ala Leu Met Asp Gln Lys

              125                 130                 135                 140
Ile Ala Asp Tyr Ala Lys Asn Lys Ala Leu Ala Glu Leu Gln Gly Leu Gln Asn Asn Val

              145                 150                 155                 160
Glu Asp Tyr Val Ser Ala Leu Ser Ser Trp Gln Lys Asn Pro Val Ser Ser Arg Asn Pro

              165                 170                 175                 180
His Ser Gln Gly Arg Ile Arg Glu Leu Phe Ser Gln Ala Glu Ser His Phe Arg Asn Ser

              185                 190                 195                 200
Met Pro Ser Phe Ala Ile Ser Gly Tyr Glu Val Leu Phe Leu Thr Thr Tyr Ala Gln Ala

              205                 210                 215                 220
Ala Asn Thr His Leu Phe Leu Leu Lys Asp Ala Gln Ile Tyr Gly Glu Glu Trp Gly Tyr

              225                 230                 235                 240
Glu Lys Glu Asp Ile Ala Glu Phe Tyr Lys Arg Gln Leu Lys Leu Thr Gln Glu Tyr Thr

              245                 250                 255                 260
Asp His Cys Val Lys Trp Tyr Asn Val Gly Leu Asp Lys Leu Arg Gly Ser Ser Tyr Glu

              265                 270                 275                 280
Ser Trp Val Asn Phe Asn Arg Tyr Arg Arg Glu Met Thr Leu Thr Val Leu Asp Leu Ile

              285                 290                 295                 300
Ala Leu Phe Pro Leu Tyr Asp Val Arg Leu Tyr Pro Lys Glu Val Lys Thr Glu Leu Thr

              305                 310                 315                 320
Arg Asp Val Leu Thr Asp Pro Ile Val Gly Val Asn Asn Leu Arg Gly Tyr Gly Thr Thr
```

Table B (cont.)

			325				330				335				340
Phe	Ser	Asn	Ile	Glu	Asn	Tyr	Ile	Arg	Lys	Pro	His	Leu	Phe	Asp	Tyr	Leu	His	Arg	Ile
			345				350				355				360
Gln	Phe	His	Thr	Arg	Phe	Gln	Pro	Gly	Tyr	Tyr	Gly	Asn	Asp	Ser	Phe	Asn	Tyr	Trp	Ser
			365				370				375				380
Gly	Asn	Tyr	Val	Ser	Thr	Arg	Pro	Ser	Ile	Gly	Ser	Asn	Asp	Ile	Ile	Thr	Ser	Pro	Phe
			385				390				395				400
Tyr	Gly	Asn	Lys	Ser	Ser	Glu	Pro	Val	Gln	Asn	Leu	Glu	Phe	Asn	Gly	Glu	Lys	Val	Tyr
			405				410				415				420
Arg	Ala	Val	Ala	Asn	Thr	Asn	Leu	Ala	Val	Trp	Pro	Ser	Ala	Val	Tyr	Ser	Gly	Val	Thr
			425				430				435				440
Lys	Val	Glu	Phe	Ser	Gln	Tyr	Asn	Asp	Gln	Thr	Asp	Glu	Ala	Ser	Thr	Gln	Thr	Tyr	Asp
			445				450				455				460
Ser	Lys	Arg	Asn	Val	Gly	Ala	Val	Ser	Trp	Asp	Ser	Ile	Asp	Gln	Leu	Pro	Pro	Glu	Thr
			465				470				475				480
Thr	Asp	Glu	Pro	Leu	Glu	Lys	Gly	Tyr	Ser	His	Gln	Leu	Asn	Tyr	Val	Met	Cys	Phe	Leu
			485				490				495				500
Met	Gln	Gly	Ser	Arg	Gly	Thr	Ile	Pro	Val	Leu	Thr	Trp	Thr	His	Lys	Ser	Val	Asp	Phe
			505				510				515				520
Phe	Asn	Met	Ile	Asp	Ser	Lys	Lys	Ile	Thr	Gln	Leu	Pro	Leu	Val	Lys	Ala	Tyr	Lys	Leu
			525				530				535				540
Gln	Ser	Gly	Ala	Ser	Val	Val	Ala	Gly	Pro	Arg	Phe	Thr	Gly	Gly	Asp	Ile	Ile	Gln	Cys
			545				550				555				560
Thr	Glu	Asn	Gly	Ser	Ala	Ala	Thr	Ile	Tyr	Val	Thr	Pro	Asp	Val	Ser	Tyr	Ser	Gln	Lys
			565				570				575				580
Tyr	Arg	Ala	Arg	Ile	His	Tyr	Ala	Ser	Thr	Ser	Gln	Ile	Thr	Phe	Thr	Leu	Ser	Leu	Asp
			585				590				595				600
Gly	Ala	Pro	Phe	Asn	Gln	Tyr	Tyr	Phe	Asp	Lys	Thr	Ile	Asn	Lys	Gly	Asp	Thr	Leu	Thr
			605				610				615				620
Tyr	Asn	Ser	Phe	Asn	Leu	Ala	Ser	Phe	Ser	Thr	Pro	Phe	Glu	Leu	Ser	Gly	Asn	Asn	Leu
			625				630				635				640
Gln	Ile	Gly	Val	Thr	Gly	Leu	Ser	Ala	Gly	Asp	Lys	Val	Tyr	Ile	Asp	Lys	Ile	Glu	Phe

Ile	Pro	Val	Asn

Table C

Family	Species	Common Name	Stages Tested	Activity
Chrysomelidae	Diabrotica undecimpunctata	Western spotted cucumber beetle	Adult, larva	+
	Pyrrhalta luteola	Elm leaf beetle	Adult, larva	++++
	Haltica tombacina	-	Adult, larva	+++
Curculionidae	Otiorhynchus sulcatus	Black vine weevil	Larva	++
Tenebrionidae	Tenebrio molitor	Yellow mealworm	Larva	++
	Tribolium castaneum	Red flour beetle	Adult, larva	-
Dermestidae	Attagenus megatoma	-	Larva	-
Ptinidae	Gibbium psylloides	-	Adult	-
Culicidae	Aedes aegypti	Yellow fever mosquito	Larva	-
Noctuidae	Spodoptera exigua	Beet armyworm	Larva	-
	Trichoplusia ni	Cabbage looper	Larva	-

Claims

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1. A nucleotide sequence which codes for molecules having the following amino-acid sequence:

```
                5                  10                  15                  20
Met Asn Pro Asn Asn Arg Ser Glu His Asp Thr Ile Lys Thr Thr Glu Asn Asn Glu Val

                25                  30                  35                  40
Pro Thr Asn His Val Gln Tyr Pro Leu Ala Glu Thr Pro Asn Pro Thr Leu Glu Asp Leu

                45                  50                  55                  60
Asn Tyr Lys Glu Phe Leu Arg Met Thr Ala Asp Asn Asn Thr Glu Ala Leu Asp Ser Ser

                65                  70                  75                  80
Thr Thr Lys Asp Val Ile Gln Lys Gly Ile Ser Val Val Gly Asp Leu Leu Gly Val Val

                85                  90                  95                 100
Gly Phe Pro Phe Gly Gly Ala Leu Val Ser Phe Tyr Thr Asn Phe Leu Asn Thr Ile Trp

               105                 110                 115                 120
Pro Ser Glu Asp Pro Trp Lys Ala Phe Met Glu Gln Val Glu Ala Leu Met Asp Gln Lys

               125                 130                 135                 140
Ile Ala Asp Tyr Ala Lys Asn Lys Ala Leu Ala Glu Leu Gln Gly Leu Gln Asn Asn Val

               145                 150                 155                 160
Glu Asp Tyr Val Ser Ala Leu Ser Ser Trp Gln Lys Asn Pro Val Ser Ser Arg Asn Pro

               165                 170                 175                 180
His Ser Gln Gly Arg Ile Arg Glu Leu Phe Ser Gln Ala Glu Ser His Phe Arg Asn Ser

               185                 190                 195                 200
Met Pro Ser Phe Ala Ile Ser Gly Tyr Glu Val Leu Phe Leu Thr Thr Tyr Ala Gln Ala

               205                 210                 215                 220
Ala Asn Thr His Leu Phe Leu Leu Lys Asp Ala Gln Ile Tyr Gly Glu Glu Trp Gly Tyr

               225                 230                 235                 240
Glu Lys Glu Asp Ile Ala Glu Phe Tyr Lys Arg Gln Leu Lys Leu Thr Gln Glu Tyr Thr

               245                 250                 255                 260
Asp His Cys Val Lys Trp Tyr Asn Val Gly Leu Asp Lys Leu Arg Gly Ser Ser Tyr Glu

               265                 270                 275                 280
Ser Trp Val Asn Phe Asn Arg Tyr Arg Arg Glu Met Thr Leu Thr Val Leu Asp Leu Ile

               285                 290                 295                 300
Ala Leu Phe Pro Leu Tyr Asp Val Arg Leu Tyr Pro Lys Glu Val Lys Thr Glu Leu Thr

               305                 310                 315                 320
Arg Asp Val Leu Thr Asp Pro Ile Val Gly Val Asn Asn Leu Arg Gly Tyr Gly Thr Thr

               325                 330                 335                 340
Phe Ser Asn Ile Glu Asn Tyr Ile Arg Lys Pro His Leu Phe Asp Tyr Leu His Arg Ile

               345                 350                 355                 360
Gln Phe His Thr Arg Phe Gln Pro Gly Tyr Tyr Gly Asn Asp Ser Phe Asn Tyr Trp Ser
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                365                 370                 375                 380
Gly Asn Tyr Val Ser Thr Arg Pro Ser Ile Gly Ser Asn Asp Ile Ile Thr Ser Pro Phe

                385                 390                 395                 400
Tyr Gly Asn Lys Ser Ser Glu Pro Val Gln Asn Leu Glu Phe Asn Gly Glu Lys Val Tyr

                405                 410                 415                 420
Arg Ala Val Ala Asn Thr Asn Leu Ala Val Trp Pro Ser Ala Val Tyr Ser Gly Val Thr

                425                 430                 435                 440
Lys Val Glu Phe Ser Gln Tyr Asn Asp Gln Thr Asp Glu Ala Ser Thr Gln Thr Tyr Asp

                445                 450                 455                 460
Ser Lys Arg Asn Val Gly Ala Val Ser Trp Asp Ser Ile Asp Gln Leu Pro Pro Glu Thr

                465                 470                 475                 480
Thr Asp Glu Pro Leu Glu Lys Gly Tyr Ser His Gln Leu Asn Tyr Val Met Cys Phe Leu

                485                 490                 495                 500
Met Gln Gly Ser Arg Gly Thr Ile Pro Val Leu Thr Trp Thr His Lys Ser Val Asp Phe

                505                 510                 515                 520
Phe Asn Met Ile Asp Ser Lys Lys Ile Thr Gln Leu Pro Leu Val Lys Ala Tyr Lys Leu

                525                 530                 535                 540
Gln Ser Gly Ala Ser Val Val Ala Gly Pro Arg Phe Thr Gly Gly Asp Ile Ile Gln Cys

                545                 550                 555                 560
Thr Glu Asn Gly Ser Ala Ala Thr Ile Tyr Val Thr Pro Asp Val Ser Tyr Ser Gln Lys

                565                 570                 575                 580
Tyr Arg Ala Arg Ile His Tyr Ala Ser Thr Ser Gln Ile Thr Phe Thr Leu Ser Leu Asp

                585                 590                 595                 600
Gly Ala Pro Phe Asn Gln Tyr Tyr Phe Asp Lys Thr Ile Asn Lys Gly Asp Thr Leu Thr

                605                 610                 615                 620
Tyr Asn Ser Phe Asn Leu Ala Ser Phe Ser Thr Pro Phe Glu Leu Ser Gly Asn Asn Leu

                625                 630                 635                 640
Gln Ile Gly Val Thr Gly Leu Ser Ala Gly Asp Lys Val Tyr Ile Asp Lys Ile Glu Phe

Ile Pro Val Asn.
```

2. DNA encoding a toxin having pesticidal activity, and having the sequence:

```
                                                ATGA ATCCGAACAA
TCGAAGTGAA CATGATACAA TAAAAACTAC TGAAAATAAT GAGGTGCCAA
CTAACCATGT TCAATATCCT TTAGCGGAAA CTCCAAATCC AACACTAGAA
GATTTAAATT ATAAAGAGTT TTTAAGAATG ACTGCAGATA ATAATACGGA
AGCACTAGAT AGCTCTACAA CAAAAGATGT CATTCAAAAA GGCATTTCCG
TAGTAGGTGA TCTCCTAGGC GTAGTAGGTT TCCCGTTTGG TGGAGCGCTT
GTTTCGTTTT ATACAAACTT TTTAAATACT ATTTGGCCAA GTGAAGACCC
GTGGAAGGCT TTTATGGAAC AAGTAGAAGC ATTGATGGAT CAGAAAATAG
CTGATTATGC AAAAAATAAA GCTCTTGCAG AGTTACAGGG CCTTCAAAAT
AATGTCGAAG ATTATGTGAG TGCATTGAGT TCATGGCAAA AAAATCCTGT
GAGTTCACGA AATCCACATA GCCAGGGGCG GATAAGAGAG CTGTTTTCTC
AAGCAGAAAG TCATTTTCGT AATTCAATGC CTTCGTTTGC AATTTCTGGA
TACGAGGTTC TATTTCTAAC AACATATGCA CAAGCTGCCA ACACACATTT
ATTTTTACTA AAAGACGCTC AAATTTATGG AGAAGAATGG GGATACGAAA
AAGAAGATAT TGCTGAATTT TATAAAAGAC AACTAAAACT TACGCAAGAA
TATACTGACC ATTGTGTCAA ATGGTATAAT GTTGGATTAG ATAAATTAAG
AGGTTCATCT TATGAATCTT GGGTAAACTT TAACCGTTAT CGCAGAGAGA
TGACATTAAC AGTATTAGAT TTAATTGCAC TATTTCCATT GTATGATGTT
CGGCTATACC CAAAAGAAGT TAAAACCGAA TTAACAAGAG ACGTTTTAAC
AGATCCAATT GTCGGAGTCA ACAACCTTAG GGGCTATGGA ACAACCTTCT
CTAATATAGA AAATTATATT CGAAAACCAC ATCTATTTGA CTATCTGCAT
AGAATTCAAT TTCACACGCG GTTCCAACCA GGATATTATG GAAATGACTC
TTTCAATTAT TGGTCCGGTA ATTATGTTTC AACTAGACCA AGCATAGGAT
CAAATGATAT AATCACATCT CCATTCTATG GAAATAAATC CAGTGAACCT
GTACAAAATT TAGAATTTAA TGGAGAAAAA GTCTATAGAG CCGTAGCAAA
TACAAATCTT GCGGTCTGGC CGTCCGCTGT ATATTCAGGT GTTACAAAAG
TGGAATTTAG CCAATATAAT GATCAAACAG ATGAAGCAAG TACACAAACG
TACGACTCAA AAAGAAATGT TGGCGCGGTC AGCTGGGATT CTATCGATCA
ATTGCCTCCA GAAACAACAG ATGAACCTCT AGAAAAGGGA TATAGCCATC
AACTCAATTA TGTAATGTGC TTTTTAATGC AGGGTAGTAG AGGAACAATC
CCAGTGTTAA CTTGGACACA TAAAAGTGTA GACTTTTTTA ACATGATTGA
TTCGAAAAAA ATTACACAAC TTCCGTTAGT AAAGGCATAT AAGTTACAAT
CTGGTGCTTC CGTTGTCGCA GGTCCTAGGT TTACAGGAGG AGATATCATT
CAATGCACAG AAAATGGAAG TGCGGCAACT ATTTACGTTA CACCGGATGT
GTCGTACTCT CAAAAATATC GAGCTAGAAT TCATTATGCT TCTACATCTC
AGATAACATT TACACTCAGT TTAGACGGGG CACCATTTAA TCAATACTAT
TTCGATAAAA CGATAAATAA AGGAGACACA TTAACGTATA ATTCATTTAA
TTTAGCAAGT TTCAGCACAC CATTCGAATT ATCAGGGAAT AACTTACAAA
TAGGCGTCAC AGGATTAAGT GCTGGAGATA AAGTTTATAT AGACAAAATT
GAATTTATTC CAGTGAAT.
```

3. A polypeptide toxin having pesticidal activity and the amino-acid sequence defined in claim 1, or a mutant thereof in which the protein secondary structure is unaltered or (in which case the biological activity is retained to some degree) altered.

4. A recombinant DNA transer vector comprising all or part of the nucleotide sequence defined in claim 2 or an equivalent nucleotide sequence containing bases whose translated region codes for the same amino-acid sequence.

5. A prokaryotic microorganism into which a DNA transfer vector according to claim 4 has been transferred and replicated.

6. A microorganism according to claim 5, which is an E . coli K-12 derivative.

7. A bacterial strain transformed to express a polypeptide toxin having pesticidal activity and the amino-acid sequence defined in claim 1.

8. E . coli (pCH-B3), NRRL B-19581.

9. Pseudomonas fluorescens transformed with plasmid pRO1614 containing the 5.8 kb DNA fragment carrying the M-7 toxin gene.

10. A hybrid recombinant plasmid capable of replication in a bacterial host, which contains expressible heterologous DNA having the nucleotide sequence defined in claim 1 or claim 2.

11. Plasmid pCHB3.

12. A plasmid according to claim 10, which is plasmid pRO1614 modified by the insertion of, at the BamHI site, a 5.8 kb DNA fragment carrying the M-7 toxin gene.

13. A live microorganism, for use in inhibiting the growth of or killing beetles of the order Coleoptera , which contains a Bacillus thuringiensis toxin gene toxic to the beetles expressed in the microorganism and coding for the toxin.

14. A microorganism according to claim 13, which is a species of Pseudomonas, Azotobacter, Erwinia, Serratia, Klebsiella, Rhizobium, Rhodopseudomonas, Methylophilius, Agrobacterium, Acetobacteror Alcaligenes.

15. A microorganism according to claim 13 or claim 14, wherein the said microorganism is pigmented and phylloplane adherent.

16. A microorganism in the form of dead, enzyme-inactivated, substantially intact unicellular cells containing an intracellular toxin which is a result of expression of a Bacillusthuringiensis toxin gene toxic to beetles of the order Coleoptera which codes for a polypeptide toxic to the beetles.

17. A microorganism according to any of claims 13 to 16, which is Pseudomonad.

18. A microorganism according to claim 17, which is of Pseudomonas fluorescens.

19. A microorganism according to claim 16, which is a prokaryote selected from Enterobacteriaceae, Bacillaceae, Rhizobiaceae , Spirilliaceae, Lactobacillaceae, Pseudomonadaceae, Azotobacteraceae and Nitrobacteraceae or a lower eukaryote selected from Phycomycetes, Ascomycetes and Basidiomycetes .

21. A microorganism according to any of claims 13 to 20, wherein the toxin is all or a toxic fragment of a parasporal crystal toxin of B. thuringiensis strain san diego.

22. A microorganism according to any of claims 13 to 20, wherein the gene DNA has the sequence defined in claim 1 or claim 2.

23. A method for producing a microorganism according to claim 16, which comprises introducing the gene into the microorganism; growing the microorganism, thereby increasing the number of cells and expressing the toxin; and killing the microorganism.

24. A method according to claim 23, wherein the cells are killed under protease-deactivating or cell wall-strengthening conditions.

25. A method according to claim 24, wherein the cells are killed using either formalin (and the toxin is its active form) or iodine.

26. A method for preparing a polypeptide toxin which is toxic to beetles of the order Coleoptera , and having the immunological properties of crystal protein of Bacillus thuringiensis strain san diego, which comprises cloning the gene encoding the polypeptide toxin into a foreign host microbe, and purifying the polypeptide toxin expressed by the foreign host microbe.

27. A method according to claim 26, wherein the foreign host microbe is Escherichia coli .

28. A method according to claim 26 or claim 27, wherein the polypeptide toxin is purified, and also isolated, by the use of an affinity column.

29. A method according to any of claims 23 to 28, where the gene DNA has the sequence defined in claim 1 or claim 2, and/or the toxin has the amino-acid sequence defined in claim 1.

European Patent Office

EUROPEAN SEARCH REPORT

Application number

DOCUMENTS CONSIDERED TO BE RELEVANT

EP 86306151.1

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A,P	EP - A2 - 0 185 005 (MONSANTO COMPANY) * Claims 1,4,12,14 * --	13,14, 16-18	C 12 N 15/00 C 07 K 13/00 C 07 H 21/04 C 12 N 1/20 C 12 P 21/00 A 01 N 63/02
A	EP - A2 - 0 063 949 (THE BOARD OF REGENTS OF THE UNIVERSITY OF WASHINGTON) * Abstract * --	13	//(C 12 N 15/00 C 12 R 1:19, 1:39, 1:07, 1:38, 1:065, 1:18, 1:425, 1:22, 1:41, 1:02, 1:05)
D,A	ZEITSCHRIFT FÜR ANGEWANDTE ENTOMOLOGIE, vol. 96, 1983 (HAMBURG, BERLIN) A. KRIEG et al. "Bacillus thuringiensis var. tenebrionis: ein neuer gegenüber Larven von Coleopteren wirksamer Pathotyp" pages 500-508 * Totality * ----	13	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

C 12 N
C 07 K
C 07 H
C 12 P
A 01 N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	29-10-1986	WOLF

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